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MIL-STD-188-196
18 June 1993

MILITARY STANDARD

BI-LEVEL IMAGE COMPRESSION

FOR THE
NATIONAL IMAGERY TRANSMISSION FORMAT STANDARD

AMSC N/A

AREA TCSS

FOREWORD

1. The National Imagery Transmission Format Standard (NITFS) is the standard for formatting digital imagery and imagery-related products and exchanging them among members of the Intelligence Community (IC), as defined by Executive Order 12333, the Department of Defense (DOD), and other departments and agencies of the United States Government, as governed by Memoranda of Agreement (MOA) with those departments and agencies.

2. The National Imagery Transmission Format Standard Technical Board (NTB) developed this standard based upon currently available technical information.

3. The DOD and members of the Intelligence Community are committed to interoperability of systems used for formatting, transmitting, receiving, and processing imagery and imagery-related information. This standard describes the one-dimensional and two-dimensional image Data compression strategy articulated in International Telecommunication Union (ITU), CCITT Recommendation T.4, *Standardization of Group 3 Facsimile Apparatus for Document Transmission*, (Geneva, 1980, amended at Malaga-Torremolinos, 1984 and Melbourne, 1988) and establishes its application within the NITFS.

4. Beneficial comments (recommendations, additions, deletions) and any pertinent Data which may be of use in improving this document should be addressed to Defense Information Systems Agency (DISA), Joint Interoperability and Engineering Organization (JIEO), Center for Standards (CFS), Attn: TBCF, 11440 Isaac Newton Square, North, Reston, VA 22090 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Scope. This standard establishes the requirements to be met by NITFS systems when image Data are compressed using the bi-level facsimile compression specified by the International Telecommunications Union (ITU) International Telegraph and Telephone Consultative Committee (CCITT) Recommendation T.4 and MIL-STD-188-161C for Group 3 facsimile devices. No attempt has been made to discuss image scanning, communication, or printing systems.

1.2 Content. This standard provides technical detail of the NITFS compression algorithm designated by the code C1 in the image compression field of the image subheader for bi-level images or overlays. It also provides the required run-length code tables for use in Secondary Imagery Dissemination Systems (SIDS) complying with NITFS.

1.3 Applicability. This standard is applicable to the Intelligence Community and the Department of Defense. It is mandatory for all Secondary Imagery Dissemination Systems in accordance with the memorandum by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence ASD(C^3I) Subject: National Imagery Transmission Format Standard (NITFS), 12 August 1991. This standard shall be implemented in accordance with the JIEO Circular 9008 and the MIL-HDBK-1300. New equipment and systems, those undergoing major modification, or those capable of rehabilitation shall conform to this standard.

1.4 Tailoring task, algorithm, or requirement specifications. The minimum compliance requirements for implementation of this compression algorithm are defined in JIEO Circular 9008.

1.5 Types of operation. This standard establishes the requirements for the communication or interchange of image Data in compressed form. The bi-level compression standard may be operated in one of three modes:

a. mode 1 - one-dimensional coding.

b. mode 2 - two-dimensional coding with standard vertical resolution, K = 2.

c. mode 3 - two-dimensional coding with higher vertical resolution, K = 4 (see 5.3.1.1).

The corresponding modes are specified by 1D, 2DS, and 2DH, respectively, in the Compression Rate Code field of the National Imagery Transmission Format (NITF) file image subheader.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

FEDERAL

FED-STD-1037B	-	Telecommunications: Glossary of Telecommunication Terms, 3 June 1991.

FEDERAL INFORMATION PROCESSING STANDARDS

FIPS PUB 147	-	Group 3 Facsimile Apparatus for Document Transmission (DOD adopted).

MILITARY

MIL-STD-188-161	-	Interoperability and Performance Standards for Digital Facsimile Equipment.
MIL-STD-2500	-	National Imagery Transmission Format for the National Imagery Transmission Format Standard (NITFS).

HANDBOOK

MIL-HDBK-1300	-	National Imagery Transmission Format Standard (NITFS) Handbook.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, 700 Robbins Avenue, Building #4, Section D, Philadelphia, PA 19111-5094.)

(Copies of Federal Information Processing Standards (FIPS) are available to Department of Defense activities from the Standardization Documents Order Desk, 700 Robbins Avenue, Building #4, Section D, Philadelphia, PA 19111-5094. Others must request copies of FIPS from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-2171.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified. Unless otherwise specified, the issues of these documents are those cited in the solicitation.

DISA/JIEO Circular 9008	-	NITFS Certification Test and Evaluation Program Plan, (Effectivity 8).

(Copies of DISA/JIEO Circular 9008 may be obtained from DISA/JIEO/JITC/TCDB, Fort Huachuca, AZ 85613-7020)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

INTERNATIONAL TELECOMMUNICATION UNION (ITU) / INTERNATIONAL TELEPHONE AND TELEGRAPH CONSULTATIVE COMMITTEE (CCITT)

CCITT Recommendation T.4	-	Standardization of Group 3 Facsimile Apparatus for Document Transmission, (Geneva, 1980, amended at Malaga-Torremolinos, 1984 and Melbourne, 1988).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI X3.4-1986	-	American National Standard Code for Information Interchange (ASCII), 1986.

(Non-Government standards and publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

(Application for copies of ANSI X3.4-1986 should be addressed to the American National Standards Institute, 1430 Broadway, New York, NY 10018-3308.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acronyms used in this standard. The following definitions are applicable for the purpose of this standard. In addition, terms used in this standard and defined in the FED-STD-1037B shall use the FED-STD-1037B definition unless otherwise noted.

a.	ANSI	American National Standards Institute
b.	ASCII	American Standard Code for Information Interchange
c.	ASD(C^3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
d.	CCITT	International Telegraph and Telephone Consultative Committee
e.	CFS	Center for Standards
f.	C^3I	Command, Control, Communications, and Intelligence
g.	DOD	Department of Defense
h.	DODISS	Department of Defense Index of Specifications and Standards
i.	DISA	Defense Information Systems Agency
j.	EOL	End of Line
k.	FIPS	Federal Information Processing Standard
l.	IC	(1) Intelligence Community (2) Image Compression
m.	JIEO	Joint Interoperability and Engineering Organization (formerly JTC^{3}A)
n.	JITC	Joint Interoperability Test Center
o.	MOA	Memoranda of Agreement
p.	NITF	National Image Transmission Format
q.	NITFS	National Image Transmission Format Standard
r.	NTB	NITFS Technical Board

s. RTC Return to Control

t. SIDS Secondary Imagery Dissemination System

3.2 Definitions used in this standard. The definitions used in this document are defined as follows:

a. Band - For the purpose of NITFS, used interchangeably with component. (See component.)

b. Bi-level image - Image information where each pixel is represented with one bit.

c. C1 - The code used to indicate the Bi-level compression algorithm in the image compression (IC) field of the image subheader.

d. CCITT group 3 - Bi-level image encoding, one- and two-dimensional, as defined in CCITT Recommendation T.4.

e. Component - For the NITFS, one of the two-dimensional arrays that comprise an image. Used interchangeably with band.

f. Fill - In NITFS context, optional Data inserted at the end of a coded image line. Fill is designated by inserting a variable length of zeroes.

g. IC - The Image Compression field of the NITF image subheader.

h. Make-up code word - Huffman code word used for run lengths greater than 64 pixels and up to 2560 pixels. A make-up code word is followed by a terminating code word.

i. Parameter K - Parameter used for two-dimensional coding of the bi-level Data. Specifies that every K line will be coded one-dimensionally. After the K^{th} line has been coded one-dimensionally, the subsequent K-1 lines will be coded two-dimensionally.

j. Pixel - For the purpose of NITFS, the smallest element from an N band image. Each pixel consists of N samples taken from corresponding locations in each of the image bands. For a single band image, sample and pixel can be used interchangeably.

k. Sample - For the NITFS, one element in the two-dimensional array that comprises a band of the image.

l. Terminating code word - Huffman code word used for run lengths of less than 64 pixels. Each encoded run length stream must end with a terminating code word.

4. GENERAL REQUIREMENTS

4.1 Interoperability. The requirements specified in this standard are intended to ensure commonality between encoding (compressing) and decoding (decompressing) one bit pixel imagery with the International Telecommunications Union (ITU) International Telegraph and Telephone Consultative Committee (CCITT) Group 3 compatible one- and two-dimensional coding algorithm. This provides Data interoperability among systems complying with NITFS. For image Data greater than one bit pixel, other NITFS specified compression algorithms should be used.

4.2 Data compression. The fundamental concept of this coding algorithm is to detect run lengths of one of two colors (for example, black or white) in an image. These run lengths are then replaced with the corresponding Huffman codes. Each coded image line is embedded within synchronization codes that indicate beginning of image, end of line, and end of image.

4.3 Encoded Data format. Figure 1 shows the NITF file format. The encoded image Data is preceded by the NITF message header and image subheaders that are initialized to the appropriate values. The Image Compression (IC) field of the image header shall be set to C1 to invoke bi-level Data compression. This standard describes the image coding process.

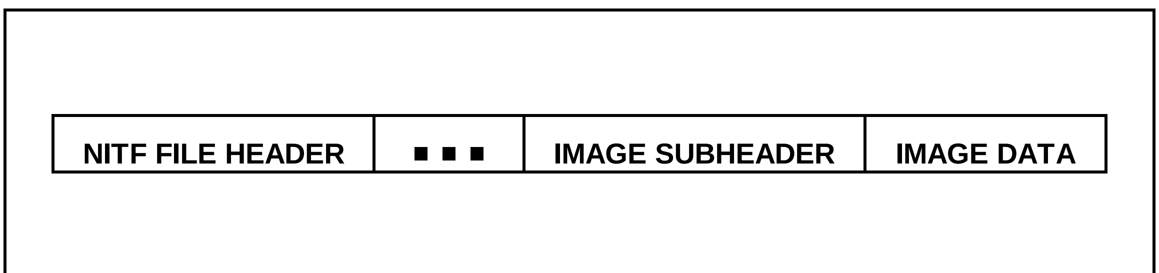

FIGURE 1. NITF file format.

4.4 Amount of compression. The amount of compression provided by any of the processes depends on the bi-level image being compressed. In some instances, expansion of the bi-level image Data may occur.

5. DETAILED REQUIREMENTS

5.1 General. This section includes detailed requirements for encoding bi-level Data that conform to the CCITT Group 3 encoding specification. The one- and two-dimensional bi-level encoding shall be performed using the Huffman codes specified in this document. Bi-level image information to be coded shall be comprised of a maximum of 2560 picture elements (pixels) for each horizontal scan line. This bi-level information shall start from the top left pixel of the image. The scan direction shall be from left to right and top to bottom.

5.1.1 Input Data. Bi-level image information shall be captured by document scanning devices or all be produced through digital process, such that the image is represented by a raster bit-map (a matrix of picture elements). The orientation of the image shall be right-reading when the matrix is rendered. The rendering process shall present pixels in horizontal scan lines from left to right, and successive scan lines, vertically from the top of the page to the bottom of the page.

5.1.2 Data Limitations. Horizontal scan lines shall not exceed 2560 pixels in length. The maximum number of scanlines shall not exceed 9999.

5.2 One-dimensional coding algorithm.

5.2.1 Coded Data. A line of coded Data is composed of a series of variable length code words. Each code word represents a run length of either all white or all black pixels, where white and black runs alternate. These run lengths, up to a maximum of 2560 pixels, shall be encoded using the code words specified in tables I, II, and III. To ensure the receiver maintains color (for example, white or black) synchronization, all Data lines start with a white run code word. If the line actually starts with a black run, a white run of zero length shall be coded initially. There are two types of code words: Terminating and Make-up. Each run length shall be encoded with either a Terminating code or with one Make-up code immediately followed by a Terminating code. Terminating codes are specified in table I[1], and they are functions of the color of the runs being encoded. Standard make-up codes with a maximum run length of 1728 pixels are given in table II [2], and again the code is a function of the color of the runs. For run lengths greater than 1728 pixels, an Extended Make-up code table is specified in table III[3]. The Extended Make-up table, unlike tables I and II, is not a function of the pixel color.

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[1]International Telecommunication Union (ITU), CCITT Recommendation T.4, *Standardization of Group 3 Facsimile Apparatus for Document Transmission*, (Geneva, 1980, amended at Malaga-Torremolinos, 1984 and Melbourne, 1988), p. 24.

[2]Ibid, p. 25.

[3]Ibid.

TABLE I. One-dimensional terminating codes.

White run length	White code word	Black run length	Black code word
0	0011 0101	0	0000 1101 11
1	0001 11	1	010
2	0111	2	11
3	1000	3	10
4	1011	4	011
5	1100	5	0011
6	1110	6	0010
7	1111	7	0001 1
8	1001 1	8	0001 01
9	1010 0	9	0001 00
10	0011 1	10	0000 100
11	0100 0	11	0000 101
12	0010 00	12	0000 111
13	0000 11	13	0000 0100
14	1101 00	14	0000 0111
15	1101 01	15	0000 1100 0
16	1010 10	16	0000 0101 11
17	1010 11	17	0000 0110 00
18	0100 111	18	0000 0010 00
19	0001 100	19	0000 1100 111
20	0001 000	20	0000 1101 000

TABLE I. One-dimensional terminating codes - Continued.

White run length	White code word	Black run length	Black code word
21	0010 111	21	0000 1101 100
22	0000 011	22	0000 0110 111
23	0000 100	23	0000 0101 000
24	0101 000	24	0000 0010 111
25	0101 011	25	0000 0011 000
26	0010 011	26	0000 1100 1010
27	0100 100	27	0000 1100 1011
28	0011 000	28	0000 1100 1100
29	0000 0010	29	0000 1100 1101
30	0000 0011	30	0000 0110 1000
31	0001 1010	31	0000 0110 1001
32	0001 1011	32	0000 0110 1010
33	0001 0010	33	0000 0110 1011
34	0001 0011	34	0000 1101 0010
35	0001 0100	35	0000 1101 0011
36	0001 0101	36	0000 1101 0100
37	0001 0110	37	0000 1101 0101
38	0001 0111	38	0000 1101 0110
39	0010 1000	39	0000 1101 0111
40	0010 1001	40	0000 0110 1100
41	0010 1010	41	0000 0110 1101

TABLE I. One-dimensional terminating codes - Continued.

White run length	White code word	Black run length	Black code word
42	0010 1011	42	0000 1101 1010
43	0010 1100	43	0000 1101 1011
44	0010 1101	44	0000 0101 0100
45	0000 0100	45	0000 0101 0101
46	0000 0101	46	0000 0101 0110
47	0000 1010	47	0000 0101 0111
48	0000 1011	48	0000 0110 0100
49	0101 0010	49	0000 0110 0101
50	0101 0011	50	0000 0101 0010
51	0101 0100	51	0000 0101 0011
52	0101 0101	52	0000 0010 0100
53	0010 0100	53	0000 0011 0111
54	0010 0101	54	0000 0011 1000
55	0101 1000	55	0000 0010 0111
56	0101 1001	56	0000 0010 1000
57	0101 1010	57	0000 0101 1000
58	0101 1011	58	0000 0101 1001
59	0100 1010	59	0000 0010 1011
60	0100 1011	60	0000 0010 1100
61	0011 0010	61	0000 0101 1010
62	0011 0011	62	0000 0110 0110

TABLE I. One-dimensional terminating codes - Continued.

White run length	White code word	Black run length	Black code word
63	0011 0100	63	0000 0110 0111

TABLE II. One-dimensional make-up codes.

White run length	White code word	Black run length	Black code word
64	1101 1	64	0000 0011 11
128	1001 0	128	0000 1100 1000
192	0101 11	192	0000 1100 1001
256	0110 111	256	0000 0101 1011
320	0011 0110	320	0000 0011 0011
384	0011 0111	384	0000 0011 0100
448	0110 0100	448	0000 0011 0101
512	0110 0101	512	0000 0011 0110 0
576	0110 1000	576	0000 0011 0110 1
640	0110 0111	640	0000 0010 0101 0
704	0110 0110 0	704	0000 0010 0101 1
768	0110 0110 1	768	0000 0010 0110 0
832	0110 1001 0	832	0000 0010 0110 1
896	0110 1001 1	896	0000 0011 1001 0
960	0110 1010 0	960	0000 0011 1001 1
1024	0110 1010 1	1024	0000 0011 1010 0
1088	0110 1011 0	1088	0000 0011 1010 1

TABLE II. One-dimensional make-up codes - Continued.

White run length	White code word	Black run length	Black code word
1152	0110 1011 1	1152	0000 0011 1011 0
1216	0110 1100 0	1216	0000 0011 1011 1
1280	0110 1100 1	1280	0000 0010 1001 0
1344	0110 1101 0	1344	0000 0010 1001 1
1408	0110 1101 1	1408	0000 0010 1010 0
1472	0100 1100 0	1472	0000 0010 1010 1
1536	0100 1100 1	1536	0000 0010 1101 0
1600	0100 1101 0	1600	0000 0010 1101 1
1664	0110 00	1664	0000 0011 0010 0
1728	0100 1101 1	1728	0000 0011 0010 1
EOL	0000 0000 0001	EOL	0000 0000 0001

TABLE III. Extended one-dimensional make-up codes.

Run length (black and white)	Make-up codes
1792	0000 0001 000
1856	0000 0001 100
1920	0000 0001 101
1984	0000 0001 0010
2048	0000 0001 0011
2112	0000 0001 0100
2176	0000 0001 0101
2240	0000 0001 0110
2304	0000 0001 0111
2368	0000 0001 1100
2432	0000 0001 1101
2496	0000 0001 1110
2560	0000 0001 1111

5.2.1.1 Coding runs less than 64 pixels. Run lengths in the range of 0 to 63 pixels are encoded with their appropriate Terminating code words.[4] The code words depend on whether the run lengths are white or black. The codes are specified in table I.

5.2.1.2 Coding runs greater than or equal to 64 pixels. Run lengths in the range of 64 to 2560 pixels are encoded first by a Make-up code followed by a Terminating code. The Make-up code word represents the maximum run length, in multiples of 64, which is equal to or shorter than the run length being encoded. The Terminating code word represents the difference between the run length being encoded and the run length represented by the Make-up code. For example, a white run length of 70 would be represented by the Make-up code word 11011 (representing a run length of 64) and a Terminating code word 1110 (representing a run length of six). Make-up codes, for run lengths greater

[4]Ibid, p. 23.

than 64 and less than or equal to 1728, depend on whether the run lengths are white or black, as shown in table II. Make-up codes, for run length greater than 1728 and less than 2560, are independent of the color of the run length, as shown in table III.

5.2.2 End of Line (EOL). Each line of coded Data shall be followed by a unique code word specifying that an EOL has occurred. This code word never can be found within a valid line of Data. In addition, this signal shall occur prior to encoding the first Data line of an image.

EOL Format: 0000 0000 0001

5.2.3 Fill. "Fill may be inserted between a line of coded Data and an EOL, but never within a line of Data." [5] Fill is necessary only when Data are encoded for facsimile devices; the amount of Fill should be determined by the specific facsimile mode, transmission rate, and transmission time requirements of a total coded line. The total coded line contains Data, Fill, and EOL.

Fill Format: variable length string of zeroes.

5.2.4 Return To Control (RTC). The end of a coded image is indicated by appending six consecutive EOLs immediately after the last line of coded Data.

5.2.5 Data organization of a one-dimensional encoded image. Figure 2 depicts the Data organization of a one-dimensionally encoded image. Prior to coding the first line of the image, an EOL shall be encoded. This is followed by individually encoded Data lines, each followed by an EOL. The end of the coded image is signified by coding an RTC after last coded image Data line. If necessary, optional FILL shall be placed between the DATA and EOL.

FIGURE 2. Data organization of a one-dimensionally encoded image.

[5] Ibid.

5.2.6 Example of a one-dimensional encoded image. Figure 3 depicts an example of a bi-level image of two lines with 12 pixels per line and the corresponding encoded binary stream. White pixels are represented by "0", and black pixels are represented by "1." The format of this encoded image is consistent with the description in 5.2.5. In this example, Fill is not used to pad the image lines.

0000 1000 1111 first line
1100 0000 0000 second line

The corresponding encoded binary stream for this image is depicted below:

EOL 1011 0101 0000 11 EOL
0011 0101 1100 111 EOL EOL EOL EOL EOL EOL
Note: EOL represents 0000 0000 0001 bit stream.

FIGURE 3. An example of an uncoded bi-level image and its one-dimensional encoded binary stream.

5.3 Two-dimensional coding algorithm. The two-dimensional coding algorithm is an extension of the one-dimensional algorithm described in 5.2.

5.3.1 Data.

5.3.1.1 Parameter K. To limit the disturbed area in the event of transmission errors, after each line coded one-dimensionally, at most, K-1 successive lines shall be coded two-dimensionally. One-dimensional coding of a line may occur more frequently than every K lines. After the first line is coded one-dimensionally, the next series of K-1 lines is coded two-dimensionally. The value for K shall be set as follows:[6]

Standard vertical resolution: K = 2
Optional higher vertical resolution: K = 4

5.3.1.2 One-dimensional coding. This conforms to the description of coded Data specified in 5.2.

[6]Ibid, p. 26.

5.3.1.3 Two-dimensional coding. This is a line-by-line coding algorithm in which the position of each changing picture element on the coding line is coded with respect to a corresponding element on the reference line. The reference line lies immediately above the line currently being coded, referred to as the coding line. After the coding line has been coded, it becomes the reference line for the next coding line.[7]

5.3.1.3.1 Definition of changing picture elements. "A changing element is defined as an element whose "colour" (i.e. black or white) is different from that of the previous element along the same scan line." (See figure 4) [8]

a_0 The reference element or starting changing element on the coding line. At the start of the coding line, a_0 is set on an imaginary white changing element situated just before the first element on the line. During the coding of the coding line, the position of a_0 is defined by the previous coding mode.[9] (See 5.3.1.3.2)

a_1 "The next changing element to the right of a_0 on the coding line.

a_2 The next changing element to the right of a_1 on the coding line.

b_1 The first changing element on the reference line to the right of a_0 and of opposite color to a_0.

b_2 The next changing element to the right of b_1 on the reference line."[10]

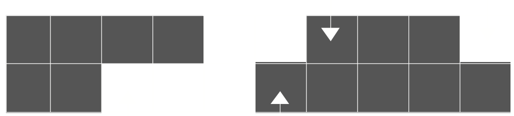

FIGURE 4. Changing picture elements.

5.3.1.3.2 Coding modes. One of three coding modes (pass, vertical, and horizontal) is chosen according to the coding procedure described in 5.3.1.3.3 to code the position of each changing element along the coding line. The following are examples of the three coding modes.

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[7]Ibid, p. 27.

[8]Ibid.

[9]Ibid.

[10]Ibid.

a. Pass mode

"This mode is identified when the position of b_2 lies to the left of a_1." This mode shall be coded using the code word 0001. (table IV). When this mode has been coded, a_0 shall be set on the element of the coding line below b_2 in preparation for the next coding (i.e., on a'_0). (See figure 5).[11] However, the state where b_2 occurs just above a_1, as shown on figure 6, shall not be considered as a pass mode. [12]

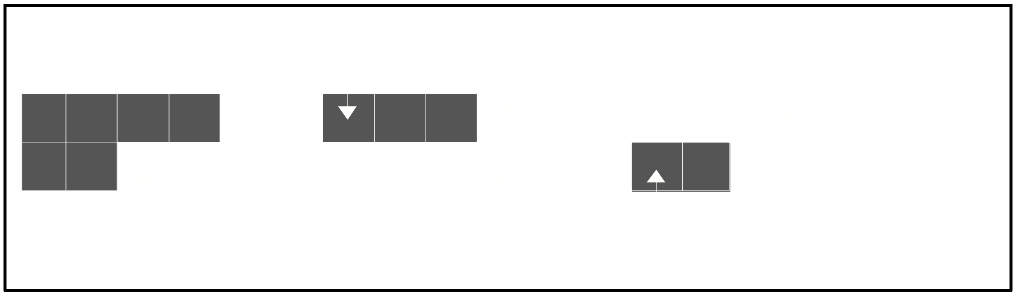

FIGURE 5. Pass mode.

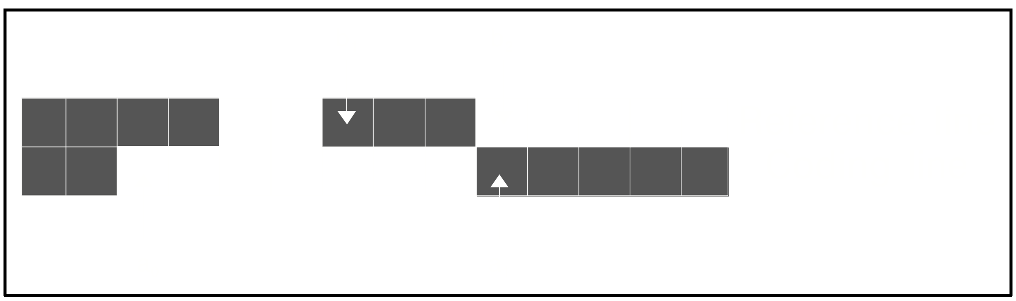

FIGURE 6. An example not corresponding to a pass mode.

[11]Ibid.

[12]Ibid, p.28.

b. Vertical mode

When the mode is not identified as a pass mode, and the absolute distance between a_1 and b_1 is less than or equal to three pixels, it is a vertical mode. Subsequently, the position of a_1 shall be coded relative to b_1. "The relative distance a_1b_1 can take on one of seven values V(0), $V_R(1)$, $V_R(2)$, $V_R(3)$, $V_L(1)$, $V_L(2)$, and $V_L(3)$, each of which is represented by a separate code word. The subscripts R and L indicate that a_1 is to the right or left respectively of b_1, and the number in brackets indicates the value of the distance a_1b_1. After vertical mode coding has occurred, the position of a_0 is set on a_1." [13]
(See figure 7)."

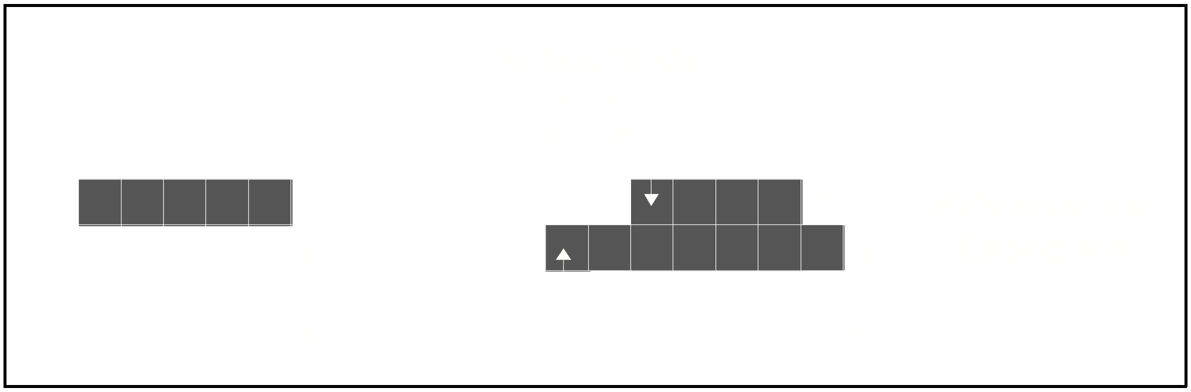

FIGURE 7. Vertical coding mode.

c. Horizontal mode

When the mode is not identified as a pass mode, and the absolute distance between a_1 and b_1 is greater than 3 pixels, it is a horizontal mode. "When this mode is identified, the run-lengths a_0a_1 and a_1a_2 shall be coded using the code words H + $M(a_0a_1)$ + $M(a_1a_2)$. H is the flag code word 001 taken from the two-dimensional code table" (table IV). $M(a_0a_1)$ and $M(a_1a_2)$ are code words representing the length and colour of the runs a_0a_1 and a_1a_2, respectively, and are taken from the appropriate white or black one-dimensional code tables (tables I, II, and III). After a horizontal mode coding, the position of a_0 is set on a_2." [14] (See figure 8).

[13] Ibid.

[14] Ibid.

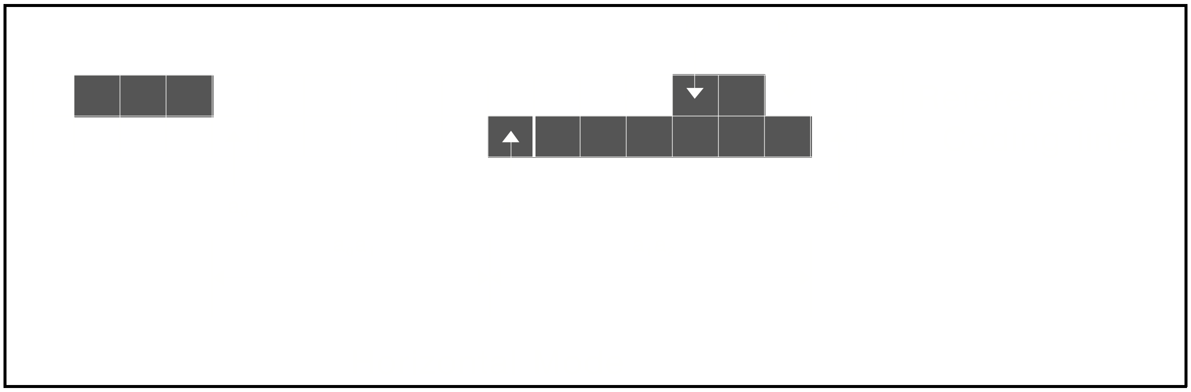

FIGURE 8. Horizontal coding mode.

5.3.1.3.3 Coding procedure. "The coding procedure identifies the coding mode to be used to code each changing element along the coding line. When one of the three coding modes has been identified according to Step 1 or Step 2 mentioned below, an appropriate code word is selected from the code table." (See table IV).[15]

"Step 1

(i) If a pass mode is identified, the code word 0001 (table IV) shall be coded. After this processing, picture element a'_0 just under b_2 is regarded as the new starting picture element a_0 for the next coding, as shown on figure 5.

(ii) If a pass mode is not detected, proceed to Step 2.

Step 2

(i) Determine the absolute value of the relative distance a_1b_1.

(ii) If $|a_1b_1| \leq 3$, as shown in table IV, a_1b_1 shall be coded by the vertical mode. Position a_1 is regarded as the new starting picture element a_0 for the next coding.

(iii) If $|a_1b_1| > 3$, as shown in table IV, following horizontal mode code 001, a_0a_1 and a_1a_2 are respectively coded by one-dimensional coding. After this processing, position a_2 is regarded as the new starting picture element a_0 for the next coding."

[15]Ibid, p. 28 and 29.

TABLE IV. Two-dimensional codes.

Mode	Elements to be coded		Notation	Code word
Pass	b_1, b_2		P	0001
Horizontal	a_0a_1, a_1a_2		H	$001+M(a_0a_1)+M(a_1a_2)$ (Note 1)
Vertical	a_1 just under b_1	$a_1b_1 = 0$	V(0)	1
	a_1 to the right of b_1	$a_1b_1 = 1$	$V_R(1)$	011
		$a_1b_1 = 2$	$V_R(2)$	000011
		$a_1b_1 = 3$	$V_R(3)$	0000011
	a_1 to the left of b_1	$a_1b_1 = 1$	$V_L(1)$	010
		$a_1b_1 = 2$	$V_L(2)$	000010
		$a_1b_1 = 3$	$V_L(3)$	0000010

Note: Code M(x) of the horizontal mode represents one-dimensional code words in tables I, II, and III.

The two-dimensional coding flow chart is shown on figure 9. [16]

[16] Ibid, p. 31.

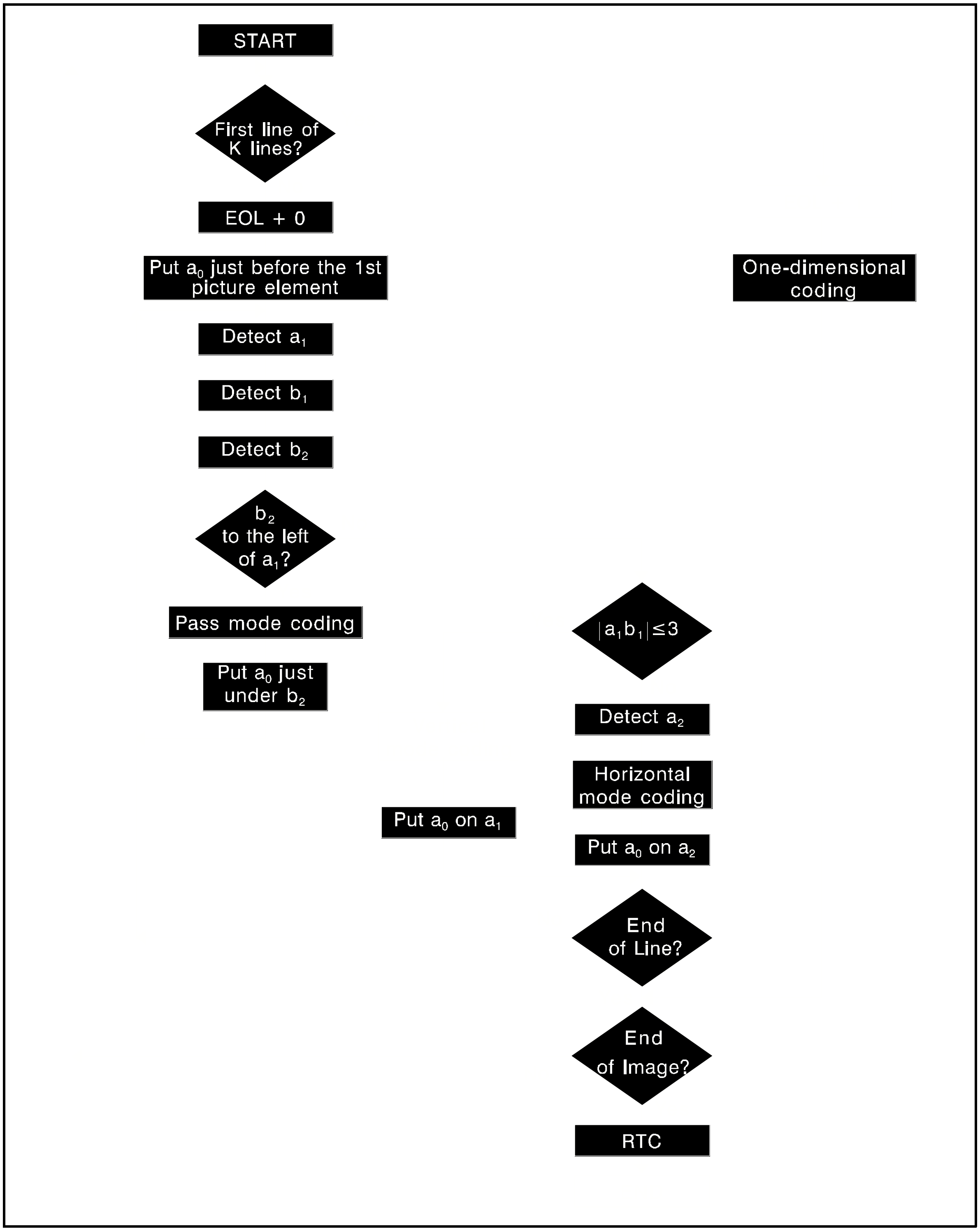

FIGURE 9. Two-dimensional coding flow diagram.

5.3.1.3.4 Variations of the algorithm. Although variations such as a single pass mode restriction are compatible with the published algorithm, variations are not supported by this standard.

5.3.1.3.5 Processing the first and last picture elements in a line.

a. Processing the first picture element

The first starting picture element a_0 on each coding line shall be set at an imaginary position just before the first picture element and shall be regarded as a white picture element. The first run length on a line a_0a_1 shall be replaced by a_0a_1-1. Therefore, if the first run is black and is chosen to be coded by horizontal mode coding, the first code word $M(a_0a_1)$ corresponds to a white run of zero length.[17]

b. Processing the last picture element

The coding of the coding line continues until the position of the imaginary changing element situated just after the last actual element has been coded. This may be coded as a_1 or a_2. Also, if b_1 or b_2 are not detected at any time during the coding of the line, they are positioned on the imaginary changing element situated just after the last actual picture element on the reference line.[18]

5.3.2 Line synchronization code word. The end-of-line code word 0000 0000 0001 is added to the end of every coded line. "The EOL code word is followed by a single tag bit that indicates whether one- or two-dimensional coding is used for the next line. In addition, EOL, plus the tag bit "1" signal, will occur prior to the first Data line of a page. Format:"[19]

EOL + 1: one-dimensional coding of the next line.
EOL + 0: two-dimensional coding of the next line.

5.3.3 Fill. Optional Fill shall be inserted between a line of coded Data and the line synchronization signal, EOL + tag bit, but shall not be inserted within the Data. Fill may be added to ensure that the transmission time of Data, Fill, and EOL, plus tag bit, is not less than the minimum transmission time of the total coded scan line.[20] This may be necessary for facsimile applications.

Format: variable length string of zeroes.

5.3.4 Return To Control (RTC). "The format used is six consecutive line synchronization code

[17] Ibid, p. 30.

[18] Ibid.

[19] Ibid.

[20] Ibid, p. 32.

words, i.e., 6 x (EOL + 1)." [21]

5.3.5 Data organization of two-dimensionally encoded image. Figure 10 depicts the Data organization of a two-dimensionally encoded image for K = 2. Figure 11 shows the Data organization of a two-dimensionally encoded image for K = 4. Prior to the first line, an EOL+1 shall be encoded. This is followed by individually coded Data lines, each followed by EOL+1 or EOL+0 depending on whether the subsequent Data line is coded one-dimensionally or two-dimensionally. The end of the image shall be signified by coding a RTC after coding the last Data line of the image. Optional FILL shall be placed between the DATA and EOL+0 of EOL+1.

FIGURE 10. Data organization of a two-dimensionally encoded image (K = 2).

[21] Ibid.

FIGURE 11. Data organization of a two-dimensional encoded image (K = 4).

5.3.6 Example of a two-dimensionally encoded image. Figure 12 shows a two-dimensional encoding example of a bi-level image formatted in the structure specified in 5.3.5. Depicted are two image lines, each containing 24 pixels; the first line is encoded one-dimensionally, and the second line is encoded two-dimensionally. A white pixel is represented by "0" and a black pixel is represented by "1". For the two-dimensional encoding, the top line is used as the reference line, and the bottom line is the coding line. Following this bi-level image example is the two-dimensionally encoded version of the image (figure 12) for parameter K=2. In this example, a white pixel is represented by "0" and a black pixel is represented by "1".

FIGURE 12. Example of a two-dimensionally encoded image (K = 2) .

6. NOTES

(This section contains general or explanatory information that may be helpful but is not mandatory).

6.1 NITF image compression field. The NITF image compression field of the NITF image header shall be specified as C1 for facsimile encoding for bi-level Data.

6.2 NITF compression rate code field. The parameter K shall be specified in the compression rate code field of the NITF image header. The parameter K shall have a standard vertical resolution of K=2, and an optional higher resolution as specified by K=4.

6.3 Resolution. The maximum number of pixels allowable in each uncoded image line shall be 2560. The NITF image header information shall reflect this limitation.

6.4 Fill. Optional fill may be governed by specific integration issues. For example, fill is inserted in T.4 facsimile devices to meet minimum line transmission time requirements as cited by section 3 of T.4.

6.5 Decoder. The decoder shall be able to interpret fill Data as well as recognize the two different vertical resolutions (K = 2 and K = 4).

6.6 Two-dimensional encoding example. Figure 13 shows the positions of parameters a0, a1, a2, b1, and b2 in the two-dimensional encoding example shown on figure 12.

FIGURE 13. Example of the two-dimensionally encoding process (K = 2) .

6.7 Subject term (key word) listing.

BWC
Compression Algorithm
Compression, Bi-level
Facsimile Compression
Group 3 facsimile
Image Compression
Imagery, Bi-level
Secondary Imagery Dissemination Systems
SIDS

CONCLUDING MATERIAL

Custodians:
Army - SC
Navy - OM
Air Force - 02

Review activities:
OASD - SO, DO, HP, IR
Army - AM, AR, MI, TM, MD, CE, SC, IE, ET, AC, PT
DLA - DH
Misc - NS, MP, DI, NA

Civil agency coordinating activities:
USDA - AFS, APS
COM - NIST
DOE
EPA
GPO
HHS - NIH
DOI - BLM, GES, MIN
DOT - CGCT

Preparing activity:
Misc - DC

Agent:
Not applicable

(Project TCSS-1960)